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Ameliorative effects of biological treatments on growth of squash plants under salt stress

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Abstract

The objective of this work was to evaluate the effect of selected biologicals on direct seeded and transplanted squash plant growth and mineral content under salinity stress. The study was conducted in pot experiments using a mixture of sandy loam soil:vermiculite (1:1, v:v) under controlled greenhouse conditions. Biologicals tested included AgBlend, SoilBuilder, Yield Shield, PlantShield, Inoculaid and Equity. Salinity treatments were established by adding 0, 50 and 100 mM of NaCl to a base complete nutrient solution (Hydro-Sol + $Ca(NO_3)_2$). Pots were irrigated with NaCl solutions and biological treatments were included in the water. Yield Shield was applied as a seed treatment. Salinity negatively affected growth of squash; however, biological treatments significantly increased fresh weight compared to non-treated plants that were challenged with salt stress. Furthermore, biological treatments tested increased the uptake of potassium compared to the non-treated control in both direct seeded and transplanted squash. Sodium concentration was not affected by biologicals in directed seeded squash except for SoilBuilder, Yield Shield and Equity at 100 mM, while AgBlend, SoilBuilder, Inoculaid and Equity decreased sodium uptake in transplants under salt stress. The most effective biologicals increased the K^+/Na^+ ratio, which was positively correlated with plant growth. Alteration of mineral uptake may be one mechanism for the alleviation of salt stress. Based on the results of the experiment reported herein, the use of biological treatments may provide a means of facilitating plant growth under salt stress.

Keywords: Squash; Biological treatments; Salt stress

1. Introduction

High concentrations of salts in soils account for large decreases in yield of a wide variety of crops all over the world. Globally, more than 770,000 km^2 of land is salt-affected by secondary salinization: 20% of irrigated land, and about 2% of dryland agricultural land (FAO, 2000). Squash is an important vegetable crop for human nutrition in the world, and squash plant growth was shown to be moderately sensitive or moderately tolerant to salinity depending on cultivar or growth stage (Francois, 1985).

Salt stress affects many aspects of plant metabolism and, as a result, growth and yields are reduced. Excess salt in the soil solution may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects. Specific ion effects may cause direct toxicity or, alternatively, the insolubility or competitive absorption of ions may affect the plant's nutritional balance (Greenway and Munns, 1980). Salinity was shown to increase the uptake of Na^+ or decrease the uptake of Ca^{2+} and K^+ (Neel et al., 2002).

Plant growth-promoting rhizobacteria (PGPR) and fungi can facilitate plant growth indirectly by reducing plant pathogens, or directly by facilitating the uptake of nutrients from the environment, by influencing phytohormone production (e.g. auxin, cytokinin, or giberallin), and/or by enzymatic lowering of plant ethylene levels (Björkman et al., 1998; Grichko and Glick, 2001). In addition to facilitating the growth of plant, plant growth-promoting microorganisms can protect plants from the deleterious effects of some environmental stresses including flooding (Grichko and Glick, 2001), drought (Mayak et al., 2004a), salt (Mayak et al., 2004b) and

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phytopathogens (Harman and Björkman, 1998). In the present study, selected biological treatments were evaluated to increase squash growth under saline conditions from direct seeded and transplanted squash.

2. Material and methods

Experiments were conducted in controlled greenhouse conditions, and plants were maintained at a day/night temperature of 24/21 °C with 14 h photoperiod during the day time at Cornell University's New York State Agricultural Experiment Station (NYSAES), Geneva in 2004 and 2005. Squash (*Cucurbita pepo* L. zucchini 'Grey') was used as plant material. The initial germination of the seed lot was 97%, and seedling emergence was uniform in all treatments.

Salinity treatments were established by adding 0, 50 and 100 mM of NaCl to a base complete nutrient solution (Hydro-Sol + $Ca(NO_3)_2$). The composition of the Hydro-Sol (Peters Fertilizers, W.R. Grace & Co., Fogelsville, PA, USA) was (ppm): N, 50; P, 48; K, 210; Mg, 30; SO_4, 117; Na, 3.619; Cl, 0.040; Fe, 3.0; Zn, 0.15; Cu, 0.15; B, 0.5; Mn, 0.5; Mo, 0.1. The solution was prepared by adding 1 g Hydro-Sol and 0.66 g $Ca(NO_3)_2$ per liter of distilled water. The electrical conductivities as well as the osmotic potentials of these solutions after adding 0, 50 and 100 mM of NaCl were determined with a conductivity meter, Basic Conductivity meter (Cole-Parmer Instrument Company) and an osmometer, Osmette Model 5004 (Precision Systems Inc.). Electrical conductivity (EC) and osmotic potential of these solutions were 1.91 dS m^{-1} with −0.0004 MPa for 0 mM NaCl, 7.03 dS m^{-1} with −0.23 MPa for 50 mM NaCl, and 11.9 dS m^{-1} with −0.45 MPa for 100 mM NaCl.

2.1. Direct seed experiment

Seeds were sown in plastic pots (10 and 7 cm top and bottom diameters, respectively, and 9-cm height, with holes in the bottom). Five seeds were sown 3 cm deep per pot, filled with a mixture of Arkport sandy loam soil:vermiculite (1:1, v:v). Moisture content of this soil medium was about 14%. Soil moisture content was increased to 60% of its water holding capacity with all biologicals (Table 1), mixed in solutions at recommended dosages by manufacturer before sowing except Yield Shield. Yield Shield was applied as a seed treatment. All pots were randomized on benches in the greenhouse. After planting, pots were covered with transparent plastic to reduce evaporation until emergence beginning. All pots were irrigated to field capacity with 0, 50 or 100 mM saline solutions to maintain the level of salinity after emergence whenever soil water content reached 70% of the available water. The pots from one replication of all treatments were weighed every day to determine when to irrigate. In the study seedling emergence was uniform in all treatments, which was statistically not important (data not shown). Individual plants were harvested from above the ground 21 days after sowing and their fresh weights determined.

2.2. Transplant experiment

Seeds of squash were planted in 128-cell Styrofoam trays (Speedling, Sun City, FL, USA) in 'Cornell Mix' (peat moss, 0.28 m^3; vermiculite, 0.34 m^3; dolomitic limestone, 4.54 kg; 10–5–10 fertilizer, 1.36 kg) with one seed per cell on 15 December 2004. During the sowing and emergence, until the transplanting stage, pots were watered with the solution prepared by adding 1 g Hydro-Sol and 0.66 g $Ca(NO_3)_2$ per liter of distilled water. Enough sized, healthy and homogeneous two squash seedlings were transplanted to plastic pots (13 and 10 cm top and bottom diameters, respectively, and 15-cm height, with holes in the bottom) with a mixture of Arkport sandy loam soil:vermiculite (1:1, v:v) on 27 December 2004. After transplanting, plants were irrigated with solutions mentioned above by adding biologicals, except Yield Shield (Table 1) at recommended dosages by the manufacturer. In the first irrigation NaCl was added to the nutrient solution at ratios of 0, 25 or 50 mM. Then 0, 50 or 100 mM of NaCl concentrations were added to solutions in later irrigations. All pots were randomized on the benches in the greenhouse. All pots were irrigated to field capacity with 0, 50 or 100 mM saline solutions to maintain the level of salinity after emergence whenever soil water content reached 70% of the available water. The pots from one replication of all treatments were weighed every day to determine when to irrigate. Plants were harvested from above the ground on 16 January 2005 and their fresh weights determined.

Table 1
Biologicals used in the study and their sources

Biologicals	Ingredients	Sources
SuperBio®AgBlend™	*Bacillus* species, microbial by-products	Advanced Microbial Solutions, LLC, 801 Hwy 377 South, PO Box 519, Pilot Point, TX 76258, USA
SuperBio®SoilBuilder™	*Bacillus* species, actinomycetes, cyanobacteria, algae, protozoa, and microbial by-products	Advanced Microbial Solutions, LLC, 801 Hwy 377 South, PO Box 519, Pilot Point, TX 76258, USA
Yield Shield	*Bacillus pumilis* GB34	Bayer CropScience 2 T.W. Alexander Drive, Research Triangle Park, NC 27709, USA
PlantShield HC	*Trichoderma harziannum*	BioWorks Inc., 51 Central Ave., Geneva, New York 14456, USA
Inoculaid	Photosynthetic bacteria	Applied and Experimental Microbiology, 7035 Phillips Highway Suite # 5-108, Jacksonville, FL 32216, USA
Equity	*Bacillus subtilis*, *Bacillus licheniformis*, *Paenibacillus polymyxa, Paenibacillus azotoformans*	Naturize BioSciences LLC, 11760 Marco Beach Drive, Suite 1, Jacksonville, FL 32224, USA